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Research article

Recent non-indigenous ascidians in the Mediterranean Sea

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Abstract

A revision of the non-indigenous ascidians in the Mediterranean Sea has been carried out, from published and unpublished records. The records considered include the last 50 years, which encompasses the period after the Pérès inventory (in 1958). Our aim is to analyze the ancient and recent records with comments about their validity and possible introduction vectors.

Key words: Ascidians, Mediterranean Sea, invasion/introduction, non-indigenous species

Introduction

The Mediterranean Sea, due to strong temperature gradients (spatially: from Alborán to Levantine Seas; and temporally: tropical in summer and temperate in winter) represents a suitable area for the introduction of species from different origins. In addition, the Mediterranean is particularly exposed to biological invasions through shipping from maritime traffic (Zibrowius 2002) and the opening of the Suez Canal (Por 1978; Galil 2000). Indeed, the Mediterranean has been progressively invaded by non-indigenous species (NIS) (Zibrowius 1992; Zenetos et al. 2005; Streftaris et al 2005; Galil 2007).

Ascidians represent one of the main biofouling taxons, particularly on ship hulls (Millar 1969; Monniot et al. 1985; Lambert 2002). They colonise all types of hard substrata, both natural and artificial (Lambert 2007), mainly in environments characterized by low-diversity fauna (e.g. estuaries, lagoons, harbors, shellfish farms, eutrophic habitats). The last inventory of littoral ascidians (< 200m depth) in the Mediterranean Sea was published over 50 years ago by Pérès (1958a). From that time new non-indigenous ascidians have become established in some sectors of the Mediterranean, through the Strait of Gibraltar and Suez Canal, or introduced by shellfish culture. In this review, we examine the geographical distribution of these species, citation of source, NIS category and possible vector of introduction. Further, we critically evaluate the validity of the citation.

Methods

Following Williamson and Fitter (1996) and Boudouresque and Verlaque (2002), a NIS must fulfil the following criteria: i) be present in a new area not previously reported; ii) the extension of its range is linked, directly or indirectly, to human activity; iii) there is a geographical discontinuity between its native area and the new area (i.e. remote dispersal); and iv) the new generations of the species are born *in situ* without human assistance, thus constituting self-sustaining populations (i.e. naturalized species).

Pérès (1958a, 1967) compiled a list of ascidians (132 species) in the Mediterranean Sea, which represented the first complete inventory of this taxon in the area. In the present review, we analyse the new records of NIS ascidians in the Mediterranean, excluding the Black Sea, including published and unpublished records (updated May 2008). We have added information, mainly from the Eastern basin (e.g., Israel, Lebanon, Cyprus, Malta, eastern Tunisia) and, in particular, from the PORTAL project (http://www.ciesm.org/marine/programs/portal; Izquierdo-Muñoz et al. 2006). The NIS have been grouped into the six categories proposed by Zenetos et al. (2005): established, casual, questionable, cryptogenic, excluded and invasive.

Results

Since 1958, ten NIS tunicates have become established and colonized some sectors of the Mediterranean (Figure 1, Annex 1). Some species have been reported only from specific habitat types rather than in the Mediterranean Sea proper. These include *Polyandrocarpa zorritensis* (Van Name, 1931), found in delta/estuarine or degraded habitats (Brunetti 1981; Turón and Perera 1988; Brunetti and Mastrototaro 2004); *Botrylloides violaceus* Oka, 1927 in the Venetian lagoon (Zaniolo et al. 1998; Occhipinti-Ambrogi 2000); and *Styela clava* Herdman, 1881, recorded recently in the Thau lagoon in France (Davis and Davis 2008). These last two species, whose origin is Japan, probably have been introduced by shell-fish cultures. Others have only been found in harbours (Corse and Tirrenian), such as *Perophora multiclathrata* (Sluiter 1904) and *Ecteinascidia styeloides* (Traustedt 1882) (Monniot 1983; Mastrototaro and Tursi 2006).

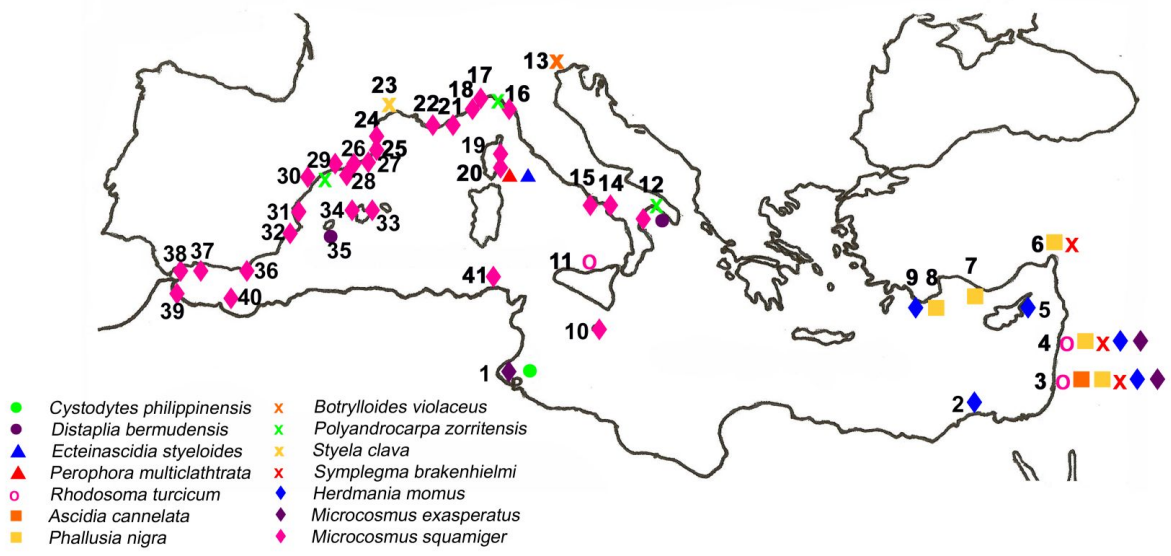

Figure 1. Location of the recent non-indigenous ascidians in the Mediterranean. The families are indicated by symbols: ● Polycitoridae ▲ Perophoridae **o** Corellidae ■ Ascidiidae **x** Styelidae ♦ Pyuridae

Some NIS have probably been misidentified with very similar species (or synonymies) or, alternatively, are very rare. For instance *Cystodytes philippinensis* Herdman 1886 and *Symplegma brakenhielmi* Michaelsen 1904 may have been mislabelled as *C. dellechiajei* and *S. viride*, respectively. Monniot and Zibrowius (1999) have demonstrated that Pérès's *Rhodosoma verecundum* is in reality *R. callense* (Lacaze-Duthiers 1865). *Distaplia bermudensis* Van Name 1902, identified only by Pérès in Iviza (1957), has been recently recorded in South Italy by Mastrototaro and Brunetti (2006).

Regarding Red Sea immigrants (Por 1978; Bitar and Kouli-Bitar 2001; Zibrowius and Bitar 2003; Streftaris et al. 2005; Zenetos et al. 2005; Bitar et al. 2007), some species have progressively spread into natural habitats in the Eastern Mediterranean, and probably will become common species in that area. These include: *Phallusia nigra* Savigny, 1816, *Herdmania momus* (Savigny, 1816) and *Symplegma brakenhielmi*, which have extended their distribution at the south of Turkey (Çinar et al. 2006). With a more constrained distribution are *Rhodosoma turcicum* (Savigny, 1816) in the north of Lebanon and Israel (Bitar and Kouli-Bitar 2001; Bitar et al. 2007; Shenkar 2008), although Mastrototaro and Tursi (2006) reported the species around Sicily island; and *Ascidia cannelata* Oken 1820 in Israel (Pérès 1958b; Izquierdo-Muñoz et al 2006; Shenkar 2008). Another possible immigrant species is *Microcosmus exasperatus* Heller, 1878, found in some localities in the Eastern Mediterranean (Meliane 2002; Izquierdo-Muñoz et al. 2006; Bitar et al. 2007; Turon et al. 2007; Shenkar 2008).

Finally, *Microcosmus squamiger* Michaelsen, 1927 (previously classified as *M. exasperatus* at western Mediterranean) was first recorded at Bizerte in 1963 (Monniot 1981) and it is now found through the Western Mediterranean (Monniot 1981; Turón 1987; Ramos-Esplá 1988; Ramos et al. 1992; Naranjo 1995; Mastrototaro and Dappiano 2005; Turón et al. 2007). In the Eastern Basin the species has been only found at Taranto, Italy (Mastrototaro and Dappiano 2005) and La Valetta harbour, Malta, on artificial substrate (pers. observ.). This species can form dense populations of agglomerated individuals in harbours and degraded habitats.

According to Zenetos et al. (2005), most ascidians introduced in the Mediterranean prior to 1958 (Pérès 1958a) must be considered as cryptogenic species. These species have not definite evidence of their native or introduced status or, else, the probable introduction occurred 'in early times'.

Discussion

Although ship-mediated introductions have been only incidentally and infrequently documented in the Mediterranean (Zibrowius 2002), the majority of NIS ascidians have probably been transported in the adult stage by shipping (across the Straits of Gibraltar and Suez Canal) attached on hulls. *Botrylloides violaceus* and *Styela clava* seem to have been recently introduced by shellfish culture (Occhipinti-Ambrogi 2000; Davis and Davis 2008). The introduction of NIS has increased in the last years (Zibrowius 1992; Zenetos et al. 2005; Streftaris et al. 2005), enhanced by the progressive tropicalization of the Mediterranean. Thus, it is highly probable that future invaders will be arriving from tropical regions (Francour et al. 1994; Boero 2002; Occhipinti-Ambrogi 2007). This is corroborated by the spread of some recent NIS ascidians with tropical affinities (*Rhodosoma turcicum, Phallusia nigra, Herdmania momus, Microcosmus exasperatus* and *M. squamiger*) in the Mediterranean.

Taxonomy and identification have been major limiting factors in the ability to detect NIS ascidians in the area. This is compounded by the lack of updated local fauna inventories and the lack of taxonomic expertise and knowledge in some Mediterranean areas (i.e., North Africa and Levantine Sea). Several NIS ascidians now known from the Mediterranean Sea were probably initially misidentified; *Cystodytes philippinesis* was reported as *C. dellechiajei, Perophora multiclathrata* as *P viridis* and *Symplegma brakenhielmi* as *S. viride*. *Ecteinascidia moorei* (cited at Alexandria by Harant 1939) has become synonymized as *E. turbinata*. A revision of the citations of these species would show a greater range of expansion.

Furthermore, some of the ancient records of NIS ascidians in the Mediterranean (before Pérès 1958a) remain uncertain, because afterwards they have never been observed. This is the case of pantropical species *Aplidium lobatum* Savigny, 1816 and *Botrylloides nigrum* Herdman, 1886 (=*Metandrocarpa nigrum*), and Indo-Pacific *Eusynstyela hartmeyeri* Michaelsen, 1904. *A. lobatum* was recorded by Savigny

(1816) at Egypt, and Pérès (1954, 1958b, 1959) at Tunisia, France, Israel and Ceuta. At this last locality, the authors have studied the ascidians (Díaz-Valdés et al. 2002), but have never observed this species. *B. nigrum* has been recorded in Tunisia and Israel (Pérès 1954, 1958b), but was probably confused with the similar species *B. leachi*. Finally, *E. hartmeyeri* has been reported only by Harant (1927) in Port Said (Egypt).

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Annex 1
Recent records of non-indigenous ascidians in the Mediterranean Sea. Year of first record, author and year of the report, the NIS category, vector and point of entry of introduction, habitats and locations colonized in the Mediterranean Sea and some observations are indicated. (RS) Red Sea and (SG) Strait of Gibraltar. Numbers for locations are shown in Figure 1

Family / Species	Year	First record by	NIS Category	Vector / Entry	Habitat / Locations	Observations
Polycitoridae						
Cystodytes philippinensis Herdman 1886	1999	Meliane 2002	cryptogenic?	ship-hull; RS or SG	Natural; 1	Pantropical; probably confused with *C. dellechiajei*
Distaplia bermudensis Van Name 1902	1953	Pérès 1957	cryptogenic	ship-hull; SG	Natural; 12,35	Amphi-Atlantic; recorded by Mastrototaro and Tursi (2006) in Italy
Corellidae						
Rhodosoma turcicum (Savigny 1816)	1999	Bitar and Kouli-Bitar 2001	established	ship-hull; RS	Natural, impoverished; 3,4, 11	Pantropical
Perophoridae						
Ecteinascidia styeloides (Traustedt 1882)	2006?	Mastrototaro and Tursi 2006	established	ship-hull; SG	Harbors; 20	Pantropical
Perophora multiclathtrata (Sluiter 1904)	1983	Monniot 1983	established	ship-hull; SG	Harbors; 20	Pantropical
Ascidiidae						
Ascidia cannelata Oken 1820	1958	Pérès 1958b	established	ship-hull; RS	Harbors; 3	Indo-Pacific
Phallusia nigra Savigny 1816	1952	Pérès 1958b	invasive	ship-hull; RS	Natural, harbors; 3, 4, 6-8	Pantropical
Styelidae						
Botrylloides violaceus Oka, 1927	1993	Occhipinti-Ambrogi 2000	casual, invasive?	shellfish culture; SG	Lagoon; 13	Japan, located in the Venice Lagoon (Italy)
Polyandrocarpa zorritensis (Van Name 1931)	1974	Brunetti 1981	established	ship-hull; SG	Delta, impoverished; 12, 30	Eastern South America
Styela clava Herdman 1882	2005	Davis and Davis 2008	casual, invasive?	shellfish culture; SG	Lagoon; 23	Japan, located in the Thau Lagoon (France)
Symplegma brakenhielmi (Michaelsen 1904)	1999	Bitar and Kouli-Bitar 2001	invasive?	ship-hull; SG	Natural, harbors; 3,4,6	Pantropical
Pyuridae						
Herdmania momus (Savigny 1816)	1939	Harant 1939	invasive	ship-hull; RS	Natural, harbors; 2-5, 9	Pantropical
Microcosmus exasperatus Heller 1878	1999	Meliane 2002	invasive?	ship-hull; RS	Natural, harbors; 1,3,4	Pantropical
Microcosmus squamiger Michaelsen 1927	1963	Monniot 1981	invasive	ship-hull; SG	Natural, harbors; 10, 14-22, 24-34, 36-41	Pantropical